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Investigation of the surface barrier discharge topology by use of intensified CCD camera

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The topology of surface barrier discharges (SBD) at atmospheric pressure in ambient air is investigated with an intensified CCD camera. The distributions of partial discharges (PD) over the alumina surface for different exposition times and different topological features of the electrode are presented and related to the temporal PD sequences. The excitation frequency is 3.7 kHz. The voltage amplitudes are in the range of 2-5 kV.

1. Introduction

The very promising type of dielectric barrier discharge (DBD) for plasma processing is surface barrier discharge (SBD) [1]. It is generated on the dielectric surfaces by alternating electrical voltage in arrangements with a structured discharge electrode on a dielectric surface and a plane induction electrode on the reverse side of the dielectric. The main applications of the SBD are ozone generation [1], exhaust gas decomposition [2] and more recently surface treatment and film deposition at atmospheric pressure [3]. Important information about the mechanism and structure of the surface discharge can be obtained from time resolved voltage and current of the discharge electrode [4] and form investigation of high speed and sensitive CCD photographs [5]. Strong influence on the PD development has the layout of the discharge electrode. It was shown by electrical measurement [4] and by electrical simulation [6]. In this work the influence of the electrode layout on the PD is investigated by use of ICCD.

2. Experiment

The discharge system described in detail in [4] consists of two electrodes separated by 0.4 mm thick, high purity Al_2O_3 ceramic plate. The discharge electrode comprises 447 holes with diameter of 1.45 mm, organized in 19 rows. Such hole is the dark circle in Fig. 1a. On the opposite side the induction electrode is formed as a 70 mm × 50 mm rectangle. A sinusoidal signal with a frequency of 3.7 kHz and voltage amplitude 2-5 kV is applied between the electrodes.

The ICCD camera PRINCETON Instruments 576-G/1 gated by pulse generator PRINCETON Instruments PG 200 is used for taking short time, down to 10 ns duration, pictures of the SBD. The sufficient sensitivity is achieved by electro-thermal cooling of the ICCD chip down to -35 C°. The macro-objective allows the magnification sufficient for observation of single PDs.

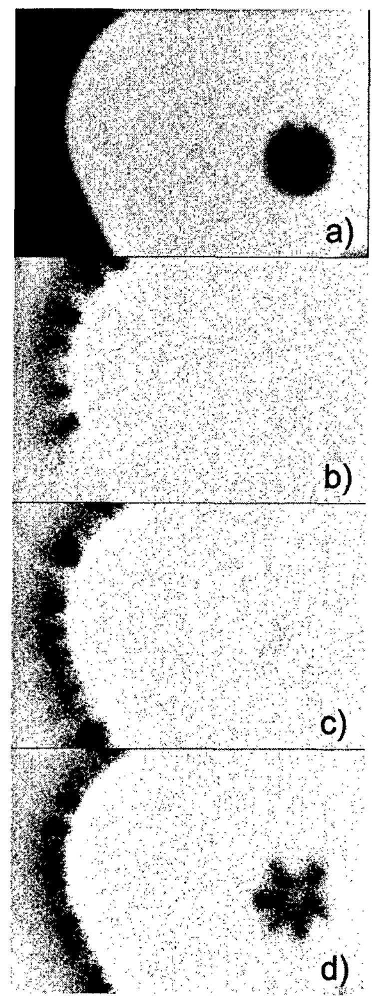

Fig. 1: Influence of the electrode edge shape on the sequence of PD ignitions. a) The electrode without discharge. The dark areas represent the Al_2O_3 surface. b), c) and d) are the inverted pictures (discharge is black) of PDs with voltage amplitudes of 3.5, 4.0 and 4.5 kV respectively. Exposition time is 10 ms.

3. Results and discussion

The shape of the electrode edge has strong influence on the ignition voltage and PD density. In Fig. 1a the fragment of the SBD electrode is shown, having three types of edge shape: convex (left top corner), linear (left low corner) and concave (hole in the electrode at the right side). With increasing voltage the PDs at the convex part of the electrode edge ignite first (Fig. 1b), followed by the linear part (Fig. 1c) and finally by concave shaped holes (Fig. 1d). It can be explained by increasing maximum electric field with increasing grade of electrode edge convexity and is in agreement with electrical measurements [4] and field simulations [7].

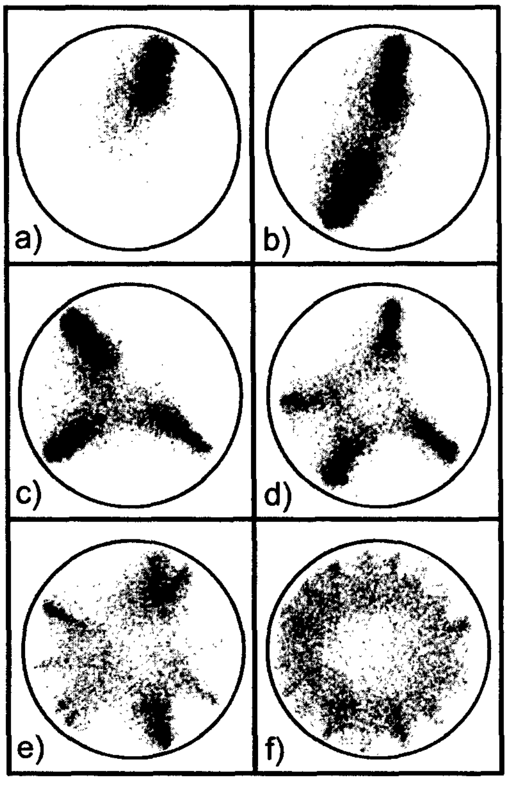

Fig.2: The inverted pictures of the discharge in the hole in the electrode (as shown in Fig. 1a). The electrode edge is shown as a circle. The exposition time is 10 ms. The voltage amplitude for a), b), c) and d) is 3.9 kV, for e) is 4.4 kV and for f) is 4.9 kV.

The observation of the SBD in the hole of the discharge electrode confirms the predictions of electrical simulation of the PD development by use of PSPICE circuit simulator. For observation time much longer than the voltage excitation period of about 0.3 ms and low voltage, it can be seen that the PDs ignite preferentially at the same position in subsequent cycles, resulting in "discrete" discharge pattern (see Fig. 2a-d). The positions of frequent PD occurrence are geometrically as far as possible, because of the repelling forces of the charge stored at the ceramic surface. This effect is less pronounced at higher voltages (see Fig. 2e and 2f) at which PDs are distributed more evenly around the electrode hole edge.

For exposition times shorter than voltage excitation period but much longer than the typical PD duration, more than one PD within exposure time can be observed. The distance between these PDs is sufficient to avoid

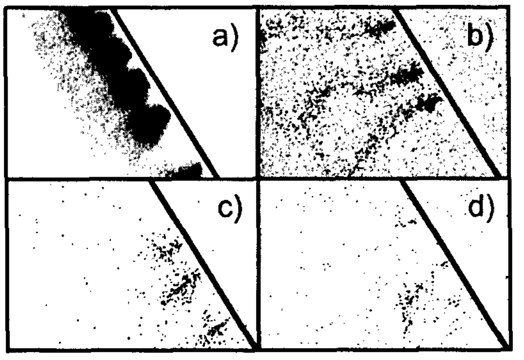

Fig.3 The inverted pictures of the discharge at the linear part of the electrode edge (as shown in Fig. 1a). The electrode edge is shown as a line. The exposition times are a) 10 ms, b) 10 μs, c) 1 μs and d) 0.1 μs. The voltage amplitude is in all cases 4.9 kV.

the suppression of the subsequent PD by the electrical charge stored during an earlier PD (see Fig. 3b and 3c).

What is somewhat surprising is, that for exposure times as short as 100 ns, still more than one PD structure can be recognized (see Fig. 3d). It means, that PDs can ignite almost simultaneously at two positions. These positions can be apart from each other. For example concurrent existence of PD at the linear part of the electrode and in the hole is observed. It means that in the time scale of a single PD, the ignited PD is not disabling the ignition of subsequent PD.

Acknowledgements:

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